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(71) Applicant : Bridgestone Corporation
No. 10-1 Kyobashi 1-Chome
Chuo-Ku
Tokyo (JP)

(72) Inventor : Takahashi, Ichiro
3-4-8 307, Ogawahigashi-cho,
Kodaira City
Tokyo (JP)
Inventor : Iwasaki, Shizuo
3-5-9 304, Ogawahigashi-cho,
Kodaira City
Tokyo (JP)
Inventor : Hayashi, Kazuo
3-5-5-635, Ogawahigashi-cho,
Kodaira City
Tokyo (JP)
Inventor : Shimizu, Nobukazu
3-5-5-823, Ogawahigashi-cho,
Kodaira City
Tokyo (JP)
Inventor : Ito, Shungo
1616-1-103, Irumagawa
Sayama City, Saitama Pref. (JP)

(74) Representative : Whalley, Kevin et al
MARKS & CLERK,
57-60 Lincoln's Inn Fields
London WC2A 3LS (GB)

(54) **Pneumatic Tires**

(57) In a tread pattern of a pneumatic tire (1) for use in high-speed, high performance vehicles, a plurality of main slant grooves (6) are arranged in the tread at a given interval in the circumferential direction of the tire and oppositely extend from positions separated by a given distance from an equatorial plane (O) of the tire at both sides thereof in a central region (T_c) of the tread toward both side ends (E) of the main tread portion (4a) at a given inclination angle with respect to the equatorial plane in a V-shaped configuration. In this case, each of the main slant grooves (6) extends in the central region (T_c) from the vicinity of the equatorial plane (O) toward a middle portion of the adjoining main slant groove in the circumferential direction in a convex arc-shaped configuration to the equatorial plane to open to the adjoining main slant groove, and an auxiliary groove (10) having a width narrower than that of the main slant groove (6) is arranged in each side region (T_s) of the main tread portion (4a) so as to communicate the main slant grooves arranged in a row in the circumferential direction of the tire to each other. In this tread pattern, a negative ratio of a ground contact portion of the tread is gradually decreased from the central region (T_c) toward the side end (E) of the tread.

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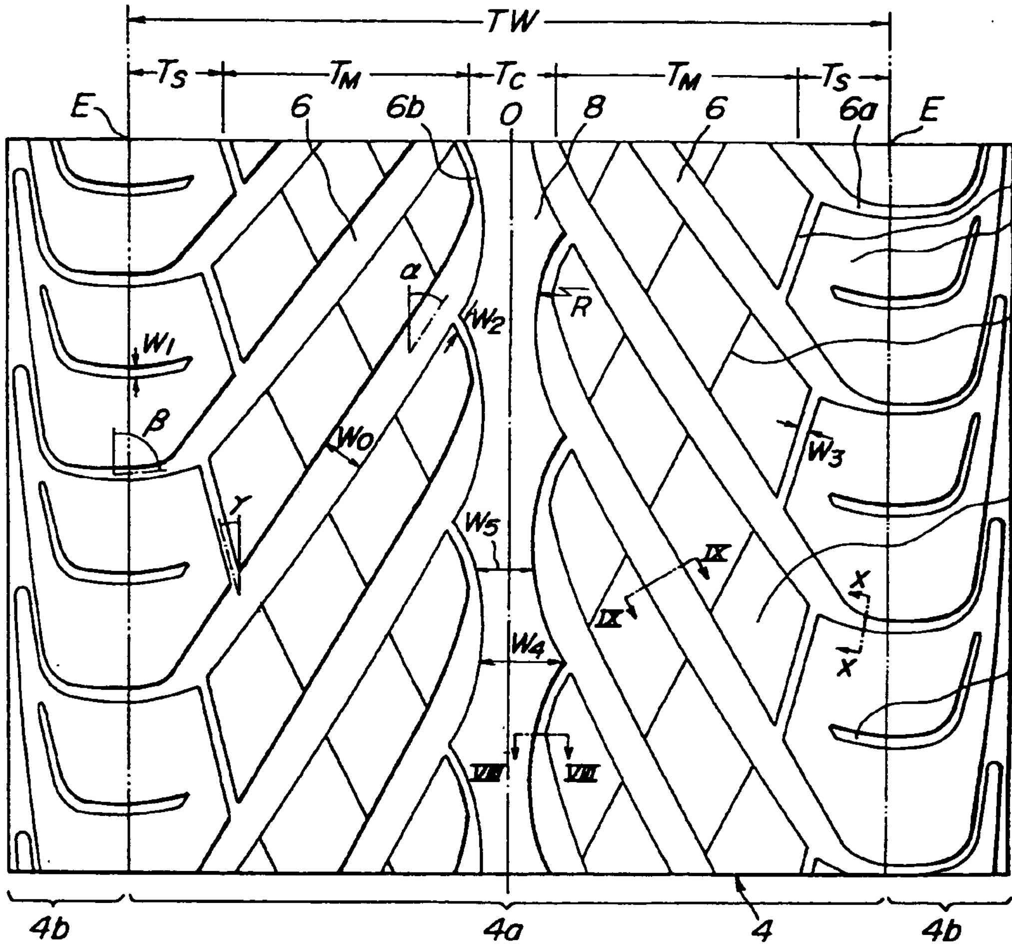
FIG_6


TW
T_S
T_M
T_C
T_M
T_S
E
6
6b
O
8
6
6a
E
10
16
14
12
18
α
W_2
R
W_1
β
W_O
W_3
γ
W_5
IX
IX
X
X
W_4
VIII
VIII
4b
4a
4
4b

This invention relates to pneumatic tires having improved high-speed running performances, and more particularly to a pneumatic radial tire for passenger cars simultaneously establishing the improvement of wet performances and the reduction of pattern noise without sacrificing the other performances of the tire.

In order to improve the high-speed running performances, the pneumatic tire of this type is usual to have a structure that a base portion of a tread is reinforced with a belt of inextensible cord plies. On the other hand, a ratio of height to width in tire section or an aspect ratio is made smaller from a viewpoint of a tire shape. In the latter case, the aspect ratio of about 0.6 is usually adapted to the tire, but there are recently appeared super-low section profile tires having an aspect ratio of 0.3.

As the tire section becomes flat, the tire width becomes wider and hence the tread width of the tire is wide. In such a tire, it is known that the steering stability on dry road surface is improved, but the drainage property of ground contact area on wet road surface is inversely degraded, so that the slipping on the wet road surface is apt to be caused during the running at a higher speed. In order to improve the running performances on the wet road surface or so-called wet performance, it is particularly important to enhance the drainage property inherent to the tread pattern. As the tread pattern having an improved drainage property, it is usual to use a combination of plural circumferential grooves each extending in a straight form in the circumferential direction of the tire and plural slant grooves crossing with each circumferential groove at a given inclination angle with respect to the circumferential direction of the tire as shown, for example, in Figs. 1a and 2a. In such a tread pattern, the excellent drainage property is attained by the circumferential grooves having a relatively wide width and also the distribution of ground contact pressure is adequate. However, the land portion of the tread is divided into blocks by the circumferential grooves and the slant grooves in order to improve the drainage property, so that the rigidity of the tread is apt to be lacking due to such a block structure to lower the steering stability. Furthermore, vibrations are created by the collision of these blocks at their stepping-in side with road surface during the running of the tire or by the friction between the block and the road surface at the stepping-in and kicking-out sides and amplituded by the circumferential grooves to leak out from the circumferential grooves to raise a problem of pattern noise.

There are known another tread patterns as shown in Figs. 3a and 4a in which the slant grooves are combined with one or two straight circumferential grooves located in a central region of the tread. In this case, the excellent drainage property is obtained, but the pattern noise is caused due to the presence of the circumferential groove likewise the aforementioned case. Moreover, the distribution of ground contact pressure is inadequate to degrade the steering stability and the uneven wear is apt to be caused.

In these conventional tread patterns, the good drainage property can be ensured by the circumferential grooves having a wide width, but the pattern noise is undesirably caused as mentioned above. In certain circumstances, the required rigidity can not be obtained in the land portion of the tread, which brings about the degradation of the resistance to uneven wear and the cornering performance.

Instead of the combination of the straight circumferential grooves and the slant grooves, there is recently noticed a tread pattern in which a plurality of main grooves each extending from a central portion of the tread toward each side end thereof in form of V-shaped configuration at a large inclination angle with respect to an axial direction of the tire are arranged on the tread to divide the tread into many land portions of V-shaped configuration. In this case, since both side regions of the tread are large in the bearing of lateral force applied during the cornering, the extending direction of the main inclined groove is changed toward the axial direction at each side region of the tread (an inclination angle of about 20° with respect to the axial direction) while holding the same groove width to enhance the rigidity of the land portion at each side region. As a result, the width of the land portion at each side region of the tread in the circumferential direction becomes undesirably wide, so that such a land portion is bifurcated at each side region by additionally arranging a lug groove having the same width as in the main groove in parallel to the main groove.

In the tire having the above tread pattern defined by the main grooves of V-shaped configuration, it can be said that the steering stability and the prevention for the generation of noise in the straight running are improved while maintaining the wet-skid performance. However, it is difficult to uniformly wear the land portion defined by the main grooves and extending in form of V-shaped configuration during the running of the tire because the wearing of the land portion at the kicking-out side is conspicuous as compared with that at the stepping-in side during the running of the tire. That is, there is caused a problem that heel and tow wear (uneven wear) is generated at a relatively initial running stage. Such a heel and tow wear is particularly violent at both side regions of the tread in which the land portion extends while decreasing the inclination angle with respect to the axial direction, and grows in respect to the depth and width as the running distance becomes longer. Finally, the appearance of the tread is injured by the such a wearing and the ground contact property is degraded, which badly affect the tire performances such as steering stability, ride comfortability against vibrations and the like.

It is, therefore, an object of the invention to provide pneumatic tires, particularly pneumatic radial tires ad-

vantageously reducing pattern noise without damaging primary performances of the tire such as steering stability, wear resistance, wet performances and the like.

According to the invention, there is the provision of a pneumatic tire comprising a pair of sidewall portions connecting to each other through a crown portion, a radial carcass of at least one rubberized cord ply toroidally extending between a pair of bead portions, a belt of inextensible cord layers superimposed about the crown portion of the carcass, and a tread superimposed on the belt and comprised of a main tread portion and a pair of side tread portions and having a tread pattern defined by a plurality of main slant grooves arranged on the tread at a given interval in a circumferential direction of the tire in which these main slant grooves oppositely extend from positions separated by a given distance from an equatorial plane of the tire at both sides thereof in a central region of the tread toward both side ends of the main tread portion so as to be inclined with respect to the circumferential direction of the tire, the improvement wherein each of said main slant grooves is extended from the central region toward the side end of the main tread portion at an inclination angle of 15-45° with respect to the circumferential direction of the tire and at an inclination angle of 75-105°in the vicinity of the side end to open at a narrow width in the side end of the main tread portion, while each of said main slant grooves is extended in the central region from the vicinity of the equatorial plane toward a middle portion of the adjoining main slant groove in the circumferential direction at a convex arc-shaped configuration to the equatorial plane to open to said adjoining main slant groove, and an auxiliary groove having a width narrower than that of the main slant groove is arranged in each side region of the main tread portion so as to communicate said main slant grooves arranged in a row in the circumferential direction of the tire to each other to form a rib continuously extending on the equatorial plane in the circumferential direction and a plurality of blocks arranged at both sides of said rib in a row in the circumferential direction, and a negative ratio of a ground contact portion of the tread is gradually decreased from the central region toward the side end of the main tread portion.

The term "main tread portion" used herein means a region of the tread contacting with ground in the straight running of the tire under 70% of a maximum design load when the tire is mounted onto a nominal rim and inflated under a nominal air pressure according to ETRTO standard for convenience' sake. Furthermore, the term "side region of the main tread portion" used herein means a region corresponding to 5-15% of a ground contact width of the tread from the side end of the main tread portion toward the equatorial plane of the tire.

In preferred embodiments of the invention, the arc-shaped portions of the main slant grooves located in the vicinity of the equatorial plane form a line substantially extending in the circumferential direction of the tire, and the width of the main slant groove is gradually reduced toward each end thereof, and the main slant grooves are alternately arranged at both sides of the equatorial plane of the tire, and the auxiliary grooves form a groove substantially extending in the circumferential direction of the tire together with a part of the main slant groove, and the position of the auxiliary groove opening in the main slant groove is within a range of 50-85% of a half of the ground contact width from the side end of the main tread portion toward the equatorial plane of the tire, and at least a part of the auxiliary groove has a depth shallower than that of the main slant groove, and a maximum width of the rib is 10-30% of the ground contact width of the tread, and the block is divided by sipes arranged in parallel with the auxiliary groove in the same direction.

The invention will be described with reference to the accompanying drawings, wherein:

Figs. 1a to 4a are schematic views illustrating various embodiments of the conventional tread pattern, respectively;

Figs. 1b to 4b are graphs showing a distribution of negative ratio in the tread patterns of Figs. 1a to 4a, respectively;

Fig. 5 is a schematically section view illustrating an outer profile of an embodiment of the pneumatic tire according to the invention;

Fig. 6 is a schematic view illustrating an embodiment of the tread pattern according to the invention;

Fig. 7 is a graph showing a distribution of negative ratio in a widthwise direction of the tire shown in Fig. 6;

Fig. 8 is a sectional view taken along a line VIII-VIII of Fig. 6;

Fig. 9 is a sectional view taken along a line IX-IX of Fig. 6;

Fig. 10 is a sectional view taken along a line X-X of Fig. 6; and

Figs. 11 and 12 are schematic views illustrating embodiments of tread patterns used in a pair of front ana rear wheel tires according to the invention, respectively.

As shown in Fig. 5, a pneumatic radial tire 1 according to the invention comprises a pair of sidewall portions 2 connecting to each other through a crown portion, a radial carcass (not shown) of at least one rubberized cord ply toroidally extending between a pair of bead portions 3, a belt (not shown) of at least two inextensible cord layers superimposed about the crown portion of the carcass, and a tread 4 superimposed on the belt and comprised of a main tread portion 4a and a pair of side tread portions 4b. The cords of the two cord layers in the belt are crossed with each other at a small cord angle with respect to the circumferential direction of the

tire. That is, the structure of the tire 1 is the same as in the conventionally known pneumatic radial tire. Moreover, the tire 1 is a super-low section profile tire having an aspect ratio of section height H to section width S of 0.35.

Fig. 6 shows a tread pattern of the tire 1 as a developed view of the tread 4. In such a tread pattern, T_C is a central region centering around an equatorial plane O of the tire at a width corresponding to 5-15% of a ground contact width TW of the main tread portion 4a, and T_M is a middle region located at both sides of the central region T_C at a width corresponding to 20-40% of the ground contact width TW, and T_S is a side region ranging from an end of the middle region T_M to a side end E of the main tread portion 4a.

In the tread pattern of Fig. 6, a plurality of main slant grooves 6 are arranged on the tread 4 at a given interval in the circumferential direction of the tire, in which these main slant grooves 6 are alternately shifted at both sides of the equatorial plane O (by a half pitch in the circumferential direction). These main slant grooves 6 oppositely extends from positions separated by a given distance from the equatorial plane O of the tire at both sides thereof in the central region T_C toward both side ends E of the main tread portion 4a so as to be inclined with respect to the circumferential direction of the tire, wherein each of the main slant grooves 6 is extended from the central region T_C through the middle region T_M toward the side end E of the main tread portion 4a at an inclination angle α of 15-45°, preferably 20-40° with respect to the circumferential direction of the tire and at an inclination angle β of 75-105° in the vicinity of the side end E or in the side region T_S to open an end portion 6a of the main slant groove 6 at a narrow width in the side end E. On the other hand, each of the main slant grooves 6 is extended in the central region T_C from the vicinity of the equatorial plane O toward a middle portion of the adjoining main slant groove 6 in the circumferential direction at a convex arc-shaped configuration to the equatorial plane O to open the other end 6b of the main slant groove 6 to the adjoining main slant groove 6. Thus, a rib 8 continuously extending in the circumferential direction of the tire is defined on the equatorial plane O of the tire by these main slant grooves 6.

Furthermore, an auxiliary groove 10 having a width narrower than that of the main slant groove 6 is arranged in each side region T_S of the main tread portion 4a at an inclination angle γ of not more than 25° with respect to the circumferential direction so as to communicate the main slant grooves 6 arranged in a row in the circumferential direction of the tire to each other to form a plurality of blocks 12 arranged at both sides of the rib 8 in a row in the circumferential direction. In the illustrated embodiment, the auxiliary groove 10 is arranged near to a boundary between the middle region T_M and the side region T_S. Each of the blocks 12 is divided into plural parts by plural sipes 14 arranged substantially in parallel with the auxiliary groove 10, preferably extending substantially perpendicular to the main slant groove 6. In the illustrated embodiment, the block 12 is divided into four parts by three sipes 14.

In the side region T_S, side blocks 16 are defined by the end portions 6a of the main slant grooves 6 arranged in a row in the circumferential direction of the tire, the auxiliary grooves 10 and the tread side end E. Each of the side blocks 16 has a notch groove 18 extending outward from the tread side end E.

The main slant groove 6 has a depth of 5-10 mm and preferably extends so as to gradually reduce a width toward each end portion of the main slant groove in such a relationship that a width W_0 in the middle region T_M is 3-7% of the ground contact width TW, and an opening width W_1 of the end portion 6a at the tread side end E is 1-4% of the ground contact width TW, and an opening width W_2 of the other end portion 6b in the adjoining main slant groove is 1-4% of the ground contact width TW. Furthermore, a radius of curvature R of the arc-shaped configuration in the end portion 6b at the side of the equatorial plane O is preferably within a range of 30-150 mm. Thus, the rib 8 defined between the end portions 6b of the main slant grooves 6 is a zigzag land portion continuously extending in the circumferential direction of the tire at a maximum width W_4 corresponding to 5-15% of the ground contact width TW and a minimum width W_5 corresponding to 3-12% of the ground contact width TW. Moreover, it is preferable that a ratio of the width W_1 to the width W_0 is within a range of 0.4-0.8.

Moreover, the auxiliary groove 10 has a width corresponding to 1-3% of the ground contact width TW and a depth of 4-7 mm. On the other hand, the notch groove 18 formed for rationalizing the rigidity in the vicinity of the tread side end E is preferable to have a width substantially equal to the opening width of the end portion 6b.

In addition, the sipe 14 has such a width that the opposed walls of the sipe are closed to each other at the ground contact area during the running under loading, or a width of about 1-3 mm.

In the tire having a tread pattern defined by the above arrangement of the grooves, the negative ratio of the ground contact portion of the tread as a whole is 25-35%, while the distribution of negative ratio in the widthwise direction of the ground contact portion is shown in Fig. 7 in which the negative ratio is maximum in a zone adjacent to the rib 8 and is tendentiously decreased toward the tread side end E. Preferably, the vicinity of the boundary between the middle region T_M and the side region T_S has a negative ratio corresponding to 50-80% of the maximum negative ratio, while the side region T_S has a negative ratio corresponding to 15-30%

of the maximum negative ratio.

For the comparison, the distribution of negative ratio in the conventional tread patterns of Figs. 1a to 4a is shown in Figs. 1b to 4b, respectively.

In the tire according to the invention, the functions taken by the main slant groove and the land portion differ in the central region T_C, middle region T_M and side region T_S of the ground contact portion of the tread. In the central region T_C, a pair of circumferential grooves located at both sides of the equatorial plane are defined by opening the end portion 6b of the main slant groove 6 in the adjoining main slant groove 6, in which the opposed groove walls of the end portion 6b are rendered into a U-shaped configuration at an inclination angle (δ, δ') of 0-10° with respect to a normal line drawn on the outer surface of the tread as shown in Fig. 8, whereby the space volume of the end portion 6b is enlarged under a restricted shape condition to improve the drainage property in the circumferential direction.

The middle region T_M is a region considering lateral force created in the cornering in addition to the drainage property. Since each of the main slant groove has a width wider than that of the end portion 6b, the land portion defined by these main slant grooves 6 is apt to generate heel and tow wear. In the invention, therefore, the opposed groove walls of the main slant groove 6 are inclined at an angle (ε, ε') of 5-20° with respect to the normal line in a U-shaped configuration and the inclination angle ε' at the stepping-in side is larger than the inclination angle ε at the kicking-out side as shown in Fig. 9, whereby the deformation of the land portion in front and back directions at the kicking-out side is controlled to prevent the occurrence of heel and tow wear.

The side region T_S is a region suffered to a large lateral force in the cornering. Particularly, the occurrence of hell and tow wear is conspicuous in the land portion of such a region. In the invention, therefore, the extending direction of the end portion 6a of the main slant groove 6 is changed substantially in parallel with the axial direction of the tire, while the opposed groove walls of the end portion 6a in the main slant groove 6 are inclined at an angle (θ, θ') of 5-15° with respect to the normal line in a U-shaped configuration and the inclination angle θ' at the stepping-in side is larger than the inclination angle θ at the kicking-out side as shown in Fig. 10, whereby the deformation of the land portion in front and back directions at the kicking-out side is controlled to prevent the occurrence of heel and tow wear.

The behavior of water in the ground contact portion of the tread on wet road surface is as follows: that is, water flows forward in the circumferential direction of the tire or at an angle of less than 20° with respect to the circumferential direction in the vicinity of the central region T_C of the tread at the stepping-in side thereof, and flows forward at an angle of 20-40° with respect to the circumferential direction in the middle region T_M of the tread, and then flows outward from the tire at an angle of more than 40° with respect to the circumferential direction in the side region T_S of the tread. In the tire according to the invention, therefore, the excellent drainage property is ensured through the division of the ground contact portion of the tread by a plurality of main slant grooves each extending at an inclination angle of 15-45° with respect to the circumferential direction of the tire in the middle region T_M and at a small inclination angle with respect to the circumferential direction at an arc-shaped configuration in the central region T_C and at a large inclination angle with respect to the circumferential direction in the side region T_S so as to met with the behavior of water on the ground contact area of the tread.

When the inclination angle of the main slant groove in the middle region of the tread is less than 15° with respect to the circumferential direction of the tire, the necessary rigidity can not be given to the blocks defined between the main slant grooves and the degradation of the steering stability and the occurrence of uneven wear are caused, while when it exceeds 45°, the drainage property can not be ensured. Similarly, the reason why the inclination angle of the main slant groove in the side region of the tread is limited to a range of 75-105° with respect to the circumferential direction is due to the fact that when it is less than 75°, the traction force is insufficient, while when it exceeds 105°, the uneven wear is caused.

Moreover, the width of the main slant groove is wider in the middle region and is gradually decreased toward both end portions to change the negative ratio as mentioned later in detail.

And also, the end portion of the main slant groove in the central region of the tread is connected at the arc-shaped configuration to the adjoining main slant groove, whereby the rib continuously extending in the circumferential direction is formed in the central region of the tread. The formation of such a rib can suppress an impact component largely influencing on the pattern noise in the central region to realize the reduction of noise. When the radius of curvature of the arc-shaped configuration in the end portion is too large, the main slant groove brings about the occurrence of columnar resonance likewise a straight groove extending in the circumferential direction of the tire, while when it is too small, the rigidity of the land portion in the vicinity of the end portion of the main slant groove extremely lowers and the uneven wear is apt to be caused. For this end, the radius of curvature of the arc-shaped configuration is preferable to be 30-150 mm.

In the tread pattern according to the invention, the arc-shaped end portion of the main slant groove is connected to the adjoining main slant groove in the central region to form a zigzag groove substantially and con-

tinuously extending in the circumferential direction of the tire, while the auxiliary groove is connected to a part of the main slant groove in the side region to form a zigzag groove substantially and continuously extending in the circumferential direction of the tire, whereby the drainage property is more improved. Furthermore, since these grooves are extended zigzag in the circumferential direction of the tire, vibration energy produced by colliding with road surface at the stepping-in side during the running of the tire is absorbed by the groove walls of these grooves to effectively reduce the noise. Moreover, the rigidities of the rib and blocks defined by these grooves are rationalized to improve the steering stability and avoid the occurrence of uneven wear.

That is, the position of the land portion decreasing the rigidity due to the presence of the groove in the widthwise direction of the tread changes on the circumference, so that the concentration of tread deformation in the low rigidity portion in the widthwise direction can be controlled to uniformize the ground contact pressure as compared with the case of existing the low rigidity portion on the same circumference through the straight groove. In case of the straight groove, the corner of the block becomes sharp and the uneven wear is promoted. On the other hand, the occurrence of the uneven wear is avoided by making the groove zigzag.

In the invention, it is preferable that the opening ends of the auxiliary groove in the side region are located from the equatorial plane toward the tread side end at a position corresponding to a range of 50-85% of a half of the ground contact width TW. When the opening position of the auxiliary groove exceeds 85%, the rigidity of the side block lowers and the lacking of the traction force and the degradation of running performances are caused to damage the steering stability, while when it is less than 50%, the desired distribution of ground contact pressure is not obtained. Preferably, the opening position is within a range of 60-75% of the half of the ground contact width TW.

Similarly, a distance between ends of the arc-shaped configurations in the opposed main slant grooves around the equatorial plane in the central region or a maximum width of the rib is preferable to be within a range of 10-30% of the half of the ground contact width TW. When the distance is less than 10%, the negative ratio in the central region becomes extremely large to degrade the steering stability and linearity in the steering (i.e. the relation between steering angle and steering force changes in linear form), while when it exceeds 30%, the improvement of the drainage property is not obtained. Preferably, the distance is within a range of 7-13% of the half of the ground contact width TW.

Furthermore, the negative ratio of the ground contact portion of the tread is gradually decreased from the central region toward the tread side end. Observing the hydroplaning phenomenon, water film is created in a zone ranging from the central region of the ground contact portion to the middle region thereof. According to the invention, therefore, the ratio of negative ratio based on the main slant groove formed from the central region to the middle region to negative ratio of the ground contact portion as a whole is made sufficiently large for contributing to the improvement of the drainage property, in which the negative ratio is made maximum at both sides of the rib and is gradually decreased toward the tread side end.

In this case, the negative ratio in the vicinity of the boundary between the middle region and the side region in a zone ranging from the central region to the middle region is 50-80% of the maximum negative ratio in a zone adjacent to the rib in view of the drainage property, while the negative ratio of the side region largely exerting on the steering stability rather than the drainage property is set to be 15-30% of the maximum negative ratio for ensuring the rigidity of the tread.

In general, tires having the same size and structure are used in front and rear wheels of a four-wheeled passenger car. In case of a high performance passenger car having a large output, however, a tire for rear wheel has frequently a size larger than that of a tire for front wheel in order to provide a road gripping force commensurating with a driving force over a wide ground contact area. As a combination of tires having different sizes, there are typically known tires for racing cars. In this case, the tires for front and rear wheels have a slick type tread pattern having no groove for fine weather or a block type tread pattern defined by plural circumferential straight grooves and many straight slant grooves crossing therewith for rainy weather. On the other hand, the high performance passenger cars usually run on general-purpose roads, so that it is required to use a pair of tires for front and rear wheels having different tire sizes and developing excellent running performances irrespectively of weather condition.

In this connection, the invention provides a pair of tire for front wheel having mainly an excellent drainage property and tire for rear wheel developing mainly an excellent gripping force under substantially the same tread pattern. According to the invention, when the combination of low section profile tires for front and rear wheels having different tire sizes and substantially the same tread pattern is applied to the above high performance passenger car, provided that the tread pattern is the same as previously mentioned, the tread width of the rear wheel tire is wider than that of the front wheel tire and the inclination angle of the main slant groove with respect to the equatorial plane in the rear wheel tire is larger than that in the front wheel tire. In such a combination of the front and rear wheel tires, therefore, when the passenger car is run on road in rainy weather, water is discharged by the front wheel tire having an excellent drainage property, while the rear wheel tire is

run on a locus of the front wheel tire immediately after the discharge of water to develop a more improved gripping force. Even in the fine weather, the excellent gripping force is developed by the rear wheel tire.

In such a pair of front and rear wheel tires according to the invention, a front wheel tire 20 and a rear wheel tire 30 have substantially the same tread pattern as shown in Figs. 11 and 12, in which the tread width TW_R of the rear wheel tire 30 is wider than the tread width TW_F of the front wheel tire 20 and the inclination angle α_R of the main slant groove 6 in the tire 30 is larger than the inclination angle α_F of the main slant groove 6 in the tire 20. The relation between the inclination angles α_F and α_R is substantially determined by the combination of the tire sizes in the tires 20 and 30, but it is favorable that the inclination angle α_F of the main slant groove 6 in the tire 20 is 20-35° and the inclination angle α_R of the main slant groove 6 in the tire 30 is 25-40° and a difference between the inclination angles α_F and α_R is within a range of 2-10°in order to sufficiently develop the functions required in these tires 20 and 30. In the embodiment of Figs. 11 and 12, the tire 20 has an aspect ratio of 0.4 and the tire 30 has an aspect ratio of 0.35, while the circumferential length of the tread is substantially the same between these tires.

Moreover, the depth of the auxiliary groove 10 in the tires 20 and 30 may be deeper in the middle region in the longitudinal direction thereof as shown in Figs. 11 and 12.

The following examples are given in illustration of the invention and are not intended as limitations thereof.

Example 1

A test tire having a tire size of 235/45ZR17 and a tread pattern shown in Fig. 6 is prepared according to a specification shown in Table 1. In this case, the ground contact width TW of the tread is 190 mm, and the circumferential length of the ground contact portion is 126 mm. Moreover, the negative ratio of the ground contact portion as a whole is 30% and the distribution of negative ratio in the widthwise direction is the same as shown in Fig. 7.

For the comparison, four tires having the same tire size as mentioned above are prepared according to the tread patterns shown in Figs. 1a to 4a, in which the circumferential groove has a width of 15 mm and a depth of 8.5 mm, and the slant groove has a width of 12 mm, a depth of 7.5 mm and an inclination angle of 30°. These tires have the distribution of negative ratio as shown in Figs. 1b to 4b, respectively.

Table 1

Main slant groove	Width	W_0 : 11 mm
		W_1 : 6 mm
		W_2 : 4 mm
	Depth	8.5 mm
	Inclination angle	α : 30°
		β : 90°
	Radius of curvature in arc-shaped configuration	R : 80 mm
Auxiliary groove	Width	W_3 : 5 mm
	Depth	5 cm
	Opening position	65.71 mm from equational plane
	Inclination angle	γ : 15°
Rib	Maximum width	W_4 : 17 mm
	Minimum width	W_5 : 15 mm
Sipe	Number of sipes	3
	Inclination angle	80°
	Width	1 mm

Each of these tires is inflated under an internal pressure of 2.5 kgf/cm^2 and mounted onto a vehicle and actually run under a two person riding load, during which the pattern noise, drainage property and steering stability are evaluated as follows:

The pattern noise is evaluated by measuring noise produced when the vehicle is inertially run from a speed of 55 km/h on a straight smooth road at a position separated by 7.5 mm from a microphone placed thereon.

The drainage property is evaluated by measuring a speed of generating the hydroplaning phenomenon when the vehicle is run on a wet road having a water depth of 10 mm.

The steering stability on a dry road surface is evaluated by a feeling test when the vehicle is run on a dry circuit having a radius of 50 m at various running modes.

The evaluated results are shown in Table 2. In this case, the result is represented by an index value on the basis that the conventional tire (Fig. 1) is 100 as a control, in which the larger the index value, the better the result.

Table 2

	Conventional tire (Fig. 1)	Conventional tire (Fig. 2)	Conventional tire (Fig. 3)	Conventional tire (Fig. 4)	Invention tire (Fig. 6)
Pattern noise	100	100	102	102	100
Drainage property	100	101	100	100	100
Steering stability	100	100	95	96	100

As seen from Table 2, the tire according to the invention can effectively reduce the pattern noise without sacrificing the drainage property while maintaining the steering stability on dry road at a sufficiently high level.

Example 2

A test tire having a tire size of 225/40ZR18 is prepared to have a tread pattern as shown in Fig. 7, in which the inclination angle α of the main slant groove 6 is 65°, and the opposed groove walls of the main slant groove 6 have inclination angles of δ= 0° and δ'= 0° in the central region, ε= 5° and ε'= 20° in the middle region and θ= 0° and θ'= 5° in the side region, and the widths W_0 and W_1 are 11 mm and 4 mm, respectively.

A comparative tire is the same as the above test tire except that the end portion 6a of the main slant groove 6 in the side region has an inclination angle β of 70° and a width W_1 equal to the width W_0 and all of the inclination angles (δ, δ', ε, ε', θ and θ') in the opposed groove walls are 0°.

Each of these tires is assembled onto a rim of 18 x 8J and inflated under an internal pressure of 2.2 kgf/cm^2 and actually run at a speed of 50-150 km/h on a course including asphalted road and general-purpose road over a distance of 4000 km. After the running, a worn quantity due to hell and tow wear is measured with respect to these tires.

As a result, the worn quantity of the invention tire is smaller by 15-30% than that of the comparative tire, and also the appearance after the wearing is considerably improved.

Example 3

A radial tire for front wheel having a tire size of 255/40R18 and a radial tire for rear wheel having a tire size of 295/35R18 are prepared according to tread patterns as shown in Figs. 11 and 12, respectively. In such a tire pair, the inclination angles α_F and α_R of the main slant groove are 28° and 33°, respectively. For the comparison, two comparative tire pairs are provided so as to have the same tread pattern as mentioned above except that the inclination angle of the main slant groove in the comparative tire pair 1 is 28° and the inclination angle of the main slant groove in the comparative tire pair 2 is 33°, respectively. In these tire pairs, the negative ratio of the front wheel tire is 33% and that of the rear wheel tire is 31%.

After the front wheel tire is assembled into a rim of 18 x 9J and the rear wheel tire is assembled into a rim of 18 x 10.5J, these tires are inflated under an internal pressure of 2.5 kgf/cm^2 and mounted onto a vehicle and actually run, during which the steering stability on dry road surface and the drainage property on wet road surface are evaluated as follows.

The steering stability is evaluated as 10 point stage by a feeling test for the degree of traction through acceleration at corner exit when the cornering limit running of the vehicle is carried out at a speed of 90-100 km/h on an asphalted circuit course. The drainage property is evaluated by measuring a speed of generating the hydroplaning phenomenon when the vehicle is run straight on a wet road having a water depth of 10 mm. The evaluated results are shown in Table 3.

Table 3

	Invention tire pair	Comparative tire pair 1	Comparative tire pair 2
Steering stability	7	5	7
Drainage property (Km/h)	84	84	79

Claims

1. A pneumatic tire (1) comprising a pair of sidewall portions (2) connecting to each other through a crown portion, a radial carcass of at least one rubberized cord ply toroidally extending between a pair of bead portions (3), a belt of inextensible cord layers superimposed about the crown portion of the carcass, and a tread (4) superimposed on the belt and comprised of a main tread portion (4a) and a pair of side tread portions (4b) and having a tread pattern defined by a plurality of main slant grooves (6) arranged on the tread at a given interval in the circumferential direction of the tire in which said main slant grooves oppositely extend from positions separated by a given distance from an equatorial plane (O) of the tire at both sides thereof in a central region (T_C) of the tread toward both side ends (E) of the main tread portion (4a) so as to be inclined with respect to the circumferential direction of the tire, characterized in that each of said main slant grooves (6) extends from the central region (T_C) toward the side end (E) of the main tread

portion (4a) at an inclination angle of 15-45° with respect to the circumferential direction of the tire and at an inclination angle of 75-105° in the vicinity of the side end (E) to open at a narrow width in the side end of the main tread portion, in that each of said main slant grooves (6) extends in the central region (T_c) from the vicinity of the equatorial plane (O) toward a middle portion of the adjoining main slant groove in the circumferential direction in a convex arc-shaped configuration to the equatorial plane to open to said adjoining main slant groove, in that an auxiliary groove (10) having a width narrower than that of the main slant groove (6) is arranged in each side region (T_s) of the main tread portion (4a) so as to communicate said main slant grooves arranged in a row in the circumferential direction of the tire to each other to form a rib (8) continuously extending on the equatorial plane in the circumferential direction and a plurality of blocks (12) arranged at both sides of said rib (8) in a row in the circumferential direction, and in that a negative ratio of a ground contact portion of the tread is gradually decreased from the central region (T_c) toward the side end (E) of the main tread portion (4a).

2. A pneumatic tire as claimed in claim 1, characterized in that the arc-shaped portions of the main slant grooves (6) located in the vicinity of the equatorial plane (O) form a line substantially extending in the circumferential direction of the tire.

3. A pneumatic tire as claimed in claim 1 or 2, characterized in that the said arc-shaped configuration has a radius of curvature (R) of 30-150 mm.

4. A pneumatic tire as claimed in any of claims 1 to 3, characterized in that the width (W_O) of the main slant groove (6) is gradually reduced toward each end thereof.

5. A pneumatic tire as claimed in any of claims 1 to 4, characterized in that the main slant grooves (6) are alternately arranged at both sides of the equatorial plane (O) of the tire.

6. A pneumatic tire as claimed in any of claims 1 to 5, characterized in that the auxiliary grooves (10) form a groove substantially extending in the circumferential direction of the tire together with a part of the main slant groove (6).

7. A pneumatic tire as claimed in any of claims 1 to 6, characterized in that the auxiliary groove (10) extends at an inclination angle of not more than 25° with respect to the circumferential direction of the tire.

8. A pneumatic tire as claimed in any of claims 1 to 7, characterized in that the position of the auxiliary groove (10) opening in the main slant groove (6) is within a range of 50-85% of a half of the ground contact width (Tw) from the side end (E) of the main tread portion (4a) toward the equatorial plane (O) of the tire.

9. A pneumatic tire as claimed in any of claims 1 to 8, characterized in that at least part of the auxiliary groove (10) has a depth shallower than that of the main slant groove (6).

10. A pneumatic tire as claimed in any of claims 1 to 9, characterized in that the maximum width of the rib (8) is 10-30% of the ground contact width (TW) of the tread.

11. A pneumatic tire as claimed in any of claims 1 to 10, characterized in that the block (12) is divided by sipes (14) arranged in parallel with the auxiliary groove (10) in the same direction.

12. A pneumatic tire as claimed in any of claims 1 to 11, characterized in that opposed groove walls of the main slant groove (6) have such a relation of inclination angle with respect to a normal line drawn from an outer surface of the tread that the inclination angle is 0-10° in the central region (T_c), 5-20° in a middle region (T_m), and 5-15° in a side region (T_s), and the inclination angle of the groove wall in the middle region (T_m) and the side region (T_s) is larger at a stepping-in side than that at a kicking-out side.

13. A pneumatic tire as claimed in any of claims 1 to 12, characterized in that when a pair of the tires for front and rear wheels are applied to a high-speed, high performance passenger car, the ground contact width of the rear wheel tire is wider than that of the front wheel tire, and the inclination angle of the main slant groove (6) in the rear wheel tire with respect to the equatorial plane (O) is larger than that in the front wheel tire.

14. A pneumatic tire (1) comprising a pair of sidewall portions (2) connecting to each other through a crown portion, a radial carcass of at least one rubberized cord ply toroidally extending between a pair of bead

portions (3), a belt of inextensible cord layers superimposed about the crown portion of the carcass, and a tread (4) superimposed on the belt and comprised of a main tread portion (4a) and a pair of side tread portions (4b) and having a tread pattern defined by a plurality of main slant grooves (6) arranged on the tread at a given interval in the circumferential direction of the tire in which said main slant grooves oppositely extend from positions separated by a given distance from an equatorial plane (O) of the tire at both sides thereof in a central region (T_c) of the tread toward both side ends (E) of the main tread portion (4a) so as to be inclined with respect to the circumferential direction of the tire, characterized in that each of said main slant grooves (6) extends from the central region (T_c) toward the side end (E) of the main tread portion (4a) at an inclination angle of 15-45° with respect to the circumferential direction of the tire and at an inclination angle of 75-105° in the vicinity of the side end (E) to open in the side end of the main tread portion, in that each of said main slant grooves (6) extends in the central region (T_c) from the vicinity of the equatorial plane (O) toward an adjacent portion of an adjoining main slant groove in the circumferential direction in an arc-shaped configuration to open to said adjoining main slant groove, in that an auxiliary groove (10) having a width narrower than that of the main slant groove (6) is arranged in or adjacent each side region (T_s) of the main tread portion (4a), and in that a negative ratio of a ground contact portion of the tread is gradually decreased from the central region (T_c) toward the side end (E) of the main tread portion (4a).

15. A pair of tires as claimed in any of claims 1 to 14, for front and rear wheels of a high-speed, high performance passenger car, characterized in that the ground contact width of the rear wheel tire is wider than that of the front wheel tire, and the inclination angle of the main slant groove (6) in the rear wheel tire with respect to the equatorial plane (O) is larger than that in the front wheel tire.

FIG_1a
PRIOR ART

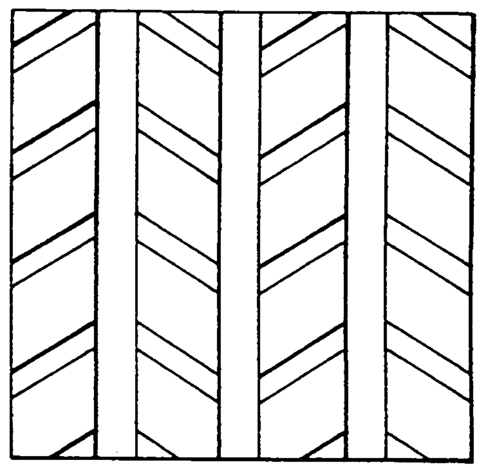


FIG_1b
PRIOR ART

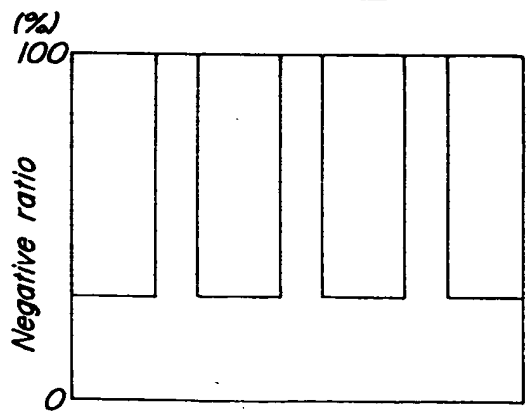


FIG_2a
PRIOR ART

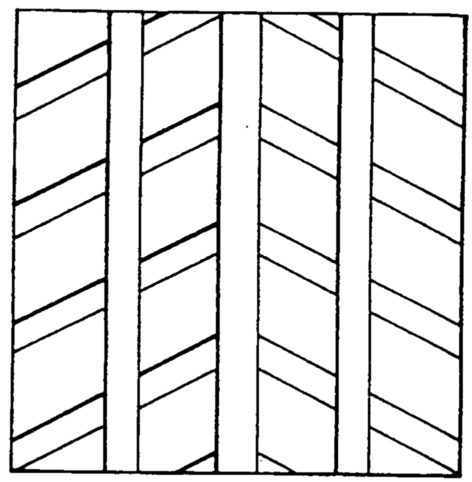


FIG_2b
PRIOR ART

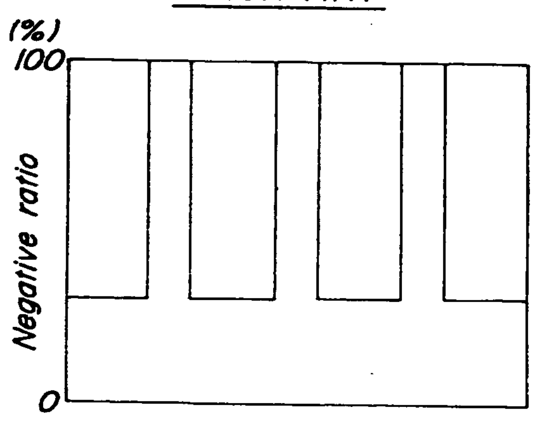


FIG_3a
PRIOR ART

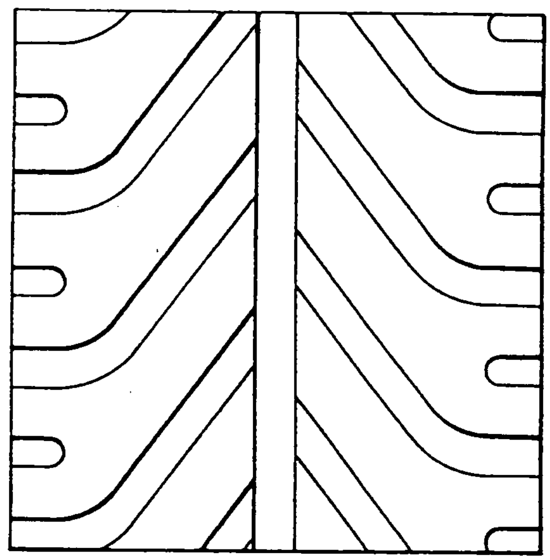


FIG_3b
PRIOR ART

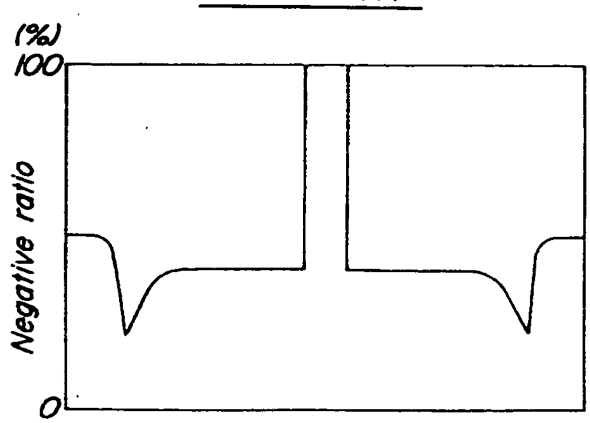


FIG_4a

PRIOR ART

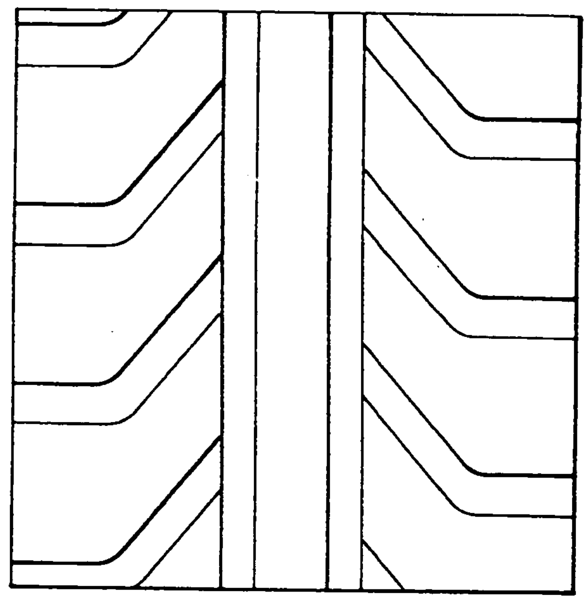


FIG_4b

PRIOR ART

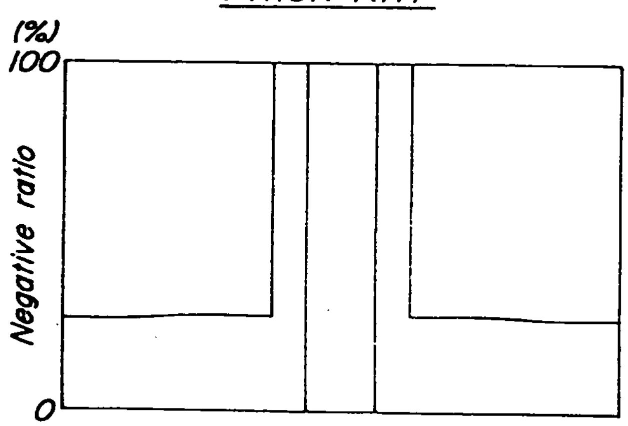


FIG_5

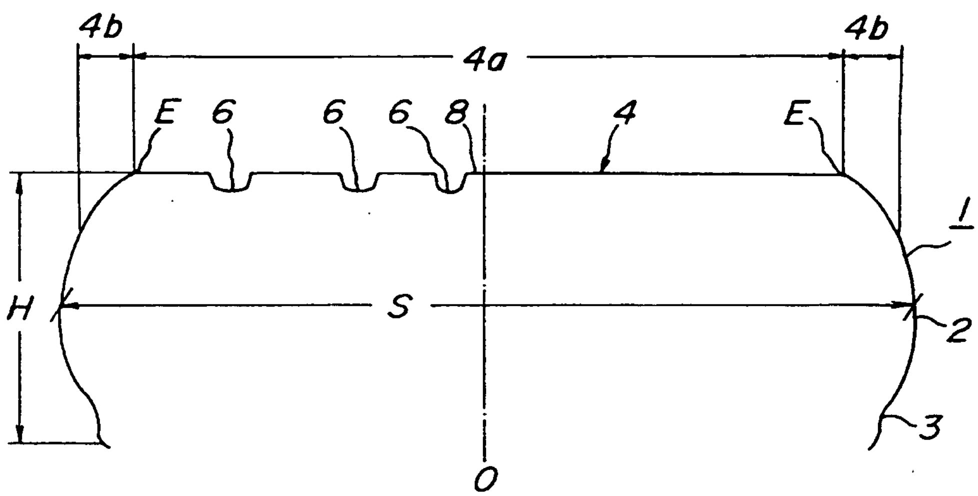


FIG_6

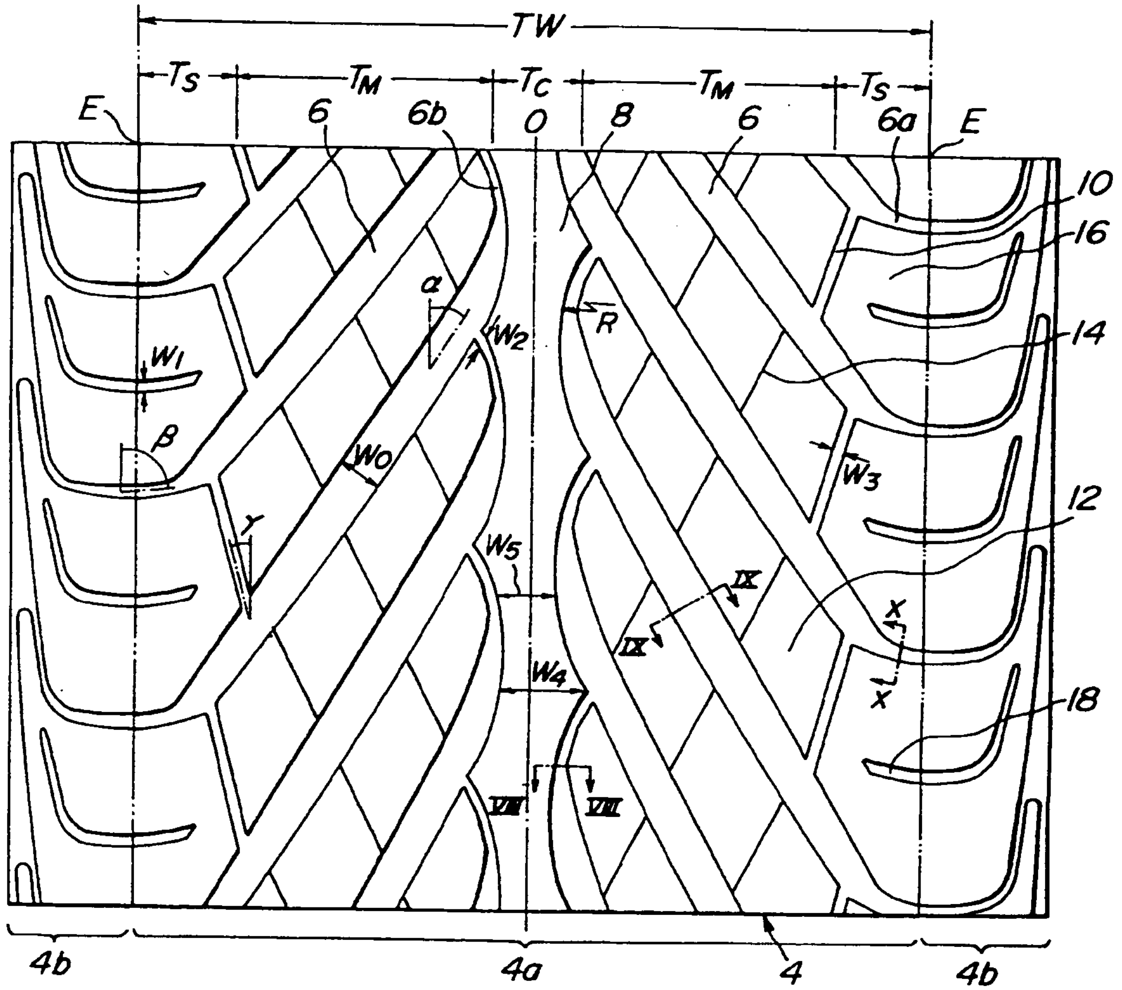

TW
TS
TM
TC
TM
TS
E
6
6b
0
8
6
6a
E
10
16
14
12
18
a
W2
R
W1
β
W0
W3
γ
W5
IX
IX
X
X
W4
VII
VII
4b
4a
4
4b

FIG_7

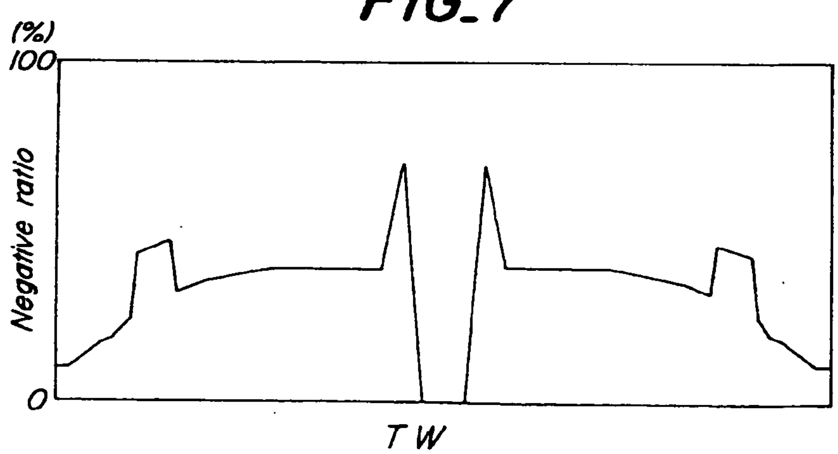

(%)
100
Negative ratio
0
TW

FIG_8

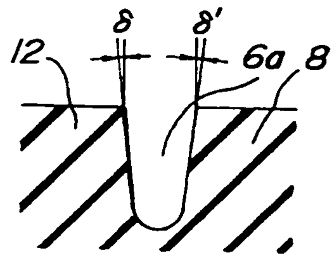


FIG_9

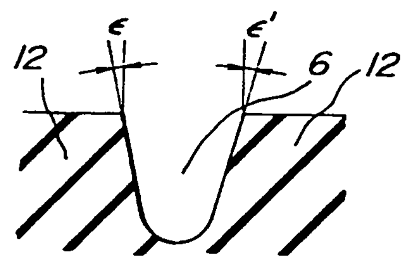


FIG_10

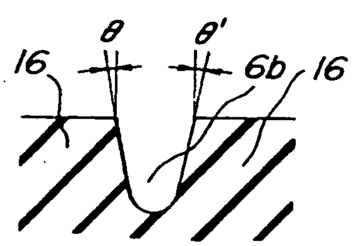


FIG_11

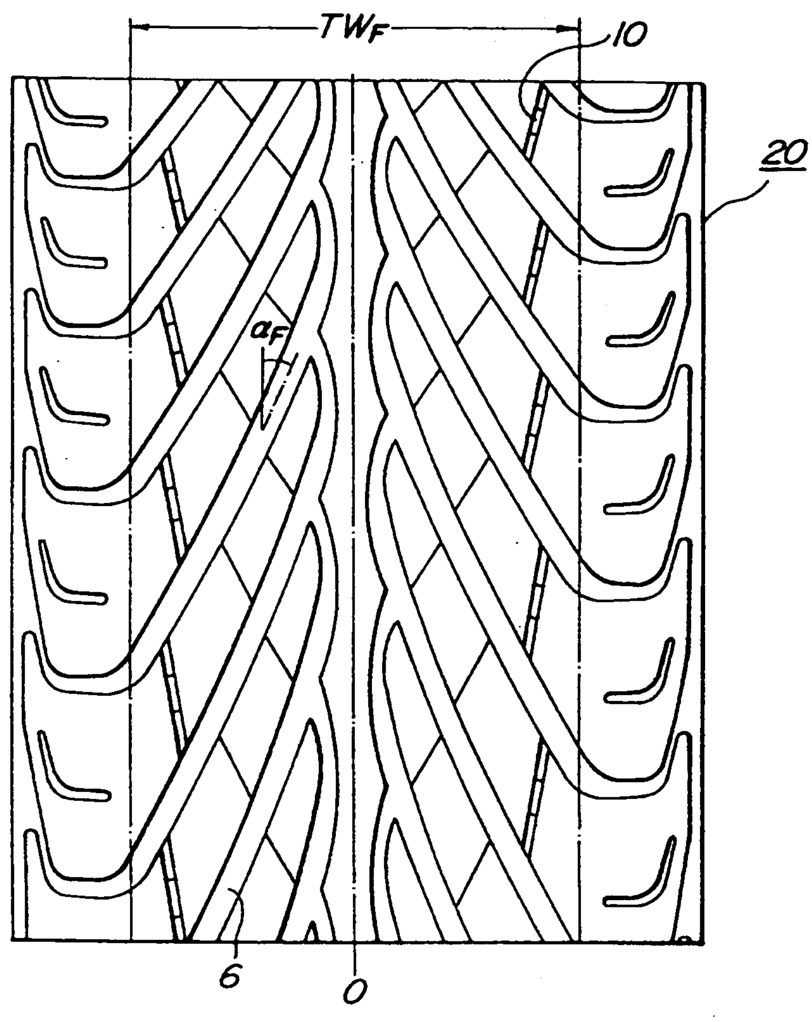


FIG_12